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ABSTRACT

Designed to assist teachers in using the microcomputer as a tool to teach problem solving strategies, this document is divided into two sections: the first introduces the concept of problem solving as a thinking process, and suggests means by which a teacher can become an effective guide for the learning of problem solving skills; the second describes a courseware package developed by the Minnesota Educational Computing Consortium (MECC) which is designed to teach problem solving techniques to middle school and junior high school students. Entitled Problem Solving Strategies, the courseware consists of one diskette for the Apple II microcomputer and a 75-page support manual containing background information on the content, instructions for classroom use, reproducible student handouts to accompany each program, and ideas for extending the strategies taught. Twelve figures are included to illustrate the flow of one program contained within the courseware and a 17-item bibliography completes the paper. (JB)

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THE MICROCOMPUTER—A PROBLEM SOLVING TOOL

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"There is no heavier burden than having a great potential."

Spoken in jest by a prominent American, this observation identifies the pressure involved when someone or something is labelled high potential.

Consider the elementary school child who is identified as a gifted student, the eighth-grade athlete who earns a starting berth on the high school soccer team, the first year educator who is chosen "Teacher of the Year." Each is considered to have high potential, each is expected to be highly successful and to continue to exhibit a strong performance within their element. Prospective performance—the level of expectation we hold for a person having extraordinary ability in a specific area—is often a tough measuring stick.

In this Information Age we examine the use of the microcomputer in education through the same looking glass. The computer is a tool with great potential. Much like the performance of a human prodigy, the use of the computer in education is evaluated according to its ability to do what we expect it to do. Initially, the computer was used extensively as a drill and practice tool—we expected it to do this. As it became clear that there were more interactive applications that could be designed for its use (e.g. simulating real-life events), we raised our level of expectation a few notches. Today we realize that we have even more areas to explore using this tool. The "burden" of having great potential as a machine extends our expectations again and again. Reactions to the use of the computer in education are as divergent as the creative minds and scrutinous eyes of the experts examining its use in classrooms.

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Unfortunately, empirical evidence regarding the effectiveness of the microcomputer in schools is seriously lacking (Becker, 1982; Ragosta, Holland, and Jamison, 1982). Most research to date has been done with terminals attached to large time-sharing computers in laboratories operated by computer specialists; the focus of most of these studies has been on improving basic skills in mathematics and language arts using drill and practice (De Vault, 1981; Hallworth and Brebner, 1980; Vinsonhaler and Bass, 1972). Educators are now interested in determining the potential of the microcomputer, the development and application of microcomputer software, and the ability to control this technology at the teacher-student level. Recent studies (Damarin, 1982; Gress, 1982; Montague, 1982) suggest that the greatest potential of the microcomputer exists in the direct teaching of higher level thinking skills rather than in drilling rote-learned rules of grammar and arithmetic.

Recently the National Commission on Excellence in Education has described our culture as A Nation At Risk. One of the indicators of this risk is described in The Excellence Report (1983):

> ...that schools may emphasize such rudiments as reading and computation at the expense of other essential skills such as comprehension, analysis, solving problems, and drawing conclusions. Many 17-year-olds do not possess the higher order intellectual skills we should expect of them. Nearly 40 percent cannot draw inference from written material; only one-fifth can write a persuasive essay; and only one-third can solve a mathematics problem requiring several steps.

Those educators claiming a greater vision toward the 21st century attempt to define the "literacies" which will help students live in our increasingly dynamic society. R.J. LaConte (1983) observes:

> The rate of change has been accelerated so much that the future bears ever less resemblance to the present. So long as education could assume a high degree of continuity, a recognizable background against which to set the new, then the future posed no particular challenge. Ground the young well in fundamentals, and let them cope with the unpredictable tomorrows as they come. But in an era in which five years of technological and social development can produce as much change as occurred in half a century, the future is much more insistent.

What are the educational implications for the use of the microcomputer? How will we measure its use as an educational tool? If the microcomputer is to be a learning tool of the future, it must prove its effectiveness (demonstrate high potential) in developing those higher level thinking skills which students today will need to meet the challenges of their world.

Problem solving—a thinking process

Thinking has been described as an adventure into the unknown, a trip on which we may let our minds soar freely (Shallcross, 1981). Our mind is free when we do not know an answer in advance, allowing us to create a method for finding out—that is, learning how answers can be arrived at and learning a means for checking results. More important, we become able to express what it is that we do not know; this requires the acquisition of skills, and skills are the result of practice in solving problems.

Problem solving is a thinking process. It is a means by which we use previously acquired knowledge and understanding to work through an unfamiliar situation. Through synthesis of this knowledge we apply the process.

Teachers and problem solving

If a teacher is to be an effective guide for the learning of problem solving skills, he or she must become an effective problem solver. Fundamental to teaching anyone how to teach problem solving is an understanding of the terms "question," "exercise," and "problem." The following example (Krulik and Rudnick, 1982) illustrates the importance of a teacher's understanding of the thinking skill levels of individual students. Consider this query:

What is the product of 7 and 6 ? or,

What is 7 x 6 ?

Is this a question? An exercise? A problem? Or is it all three? It depends on our experience with mathematics. To a mathematics instructor, the answer 42 is automatic, a recall based on years of experience. For this person it is a question—it involves only recall.

If we ask an elementary school student who has been studying multiplication, the inquiry is different. We are providing drill and practice for the student. "What is 7 x 6?" becomes an exercise—it involves practice.

Finally, if we ask this of a first grader who has not learned the meaning of multiplication, the meaning of "product" must be discussed. The student must be led to understand that 7 x 6 means taking 7 groups of 6 objects and finding the total number of objects. To this student we have presented a problem—something that requires thought.

The notion of teaching problem solving, then, must begin with the realization that what is a problem for one person can easily be an exercise or a question for someone else. Furthermore, what is a problem to one person at one time may be an exercise or even a question at a later time. This is the essence of building a base of knowledge from which to solve problems efficiently.

Teachers, students, and problem solving

The goal of teaching problem solving is to help students successfully develop a process. The eventual answer or solution to a problem is important, but the process is the heart of problem solving. A simple model applied in recent research on critical thinking skills uses the mnemonic "Up We Go" (Bass and Perkins, 1984). Students work through the five-step process to solve a problem:

I. Understand the Problem

A. What is the problem?

B. What is the goal?

C. What information is available?

1) identify important information

2) identify irrelevant information

D. What other information is needed to achieve the goal?

E. Hints

1) look for key words

2) restate the problem in your own words

3) picture the problem in your mind

II. Plan Strategy

A. Is the problem similar to one you've worked with before?

B. Can it be changed to look like a familiar problem?

C. Can it be broken into parts?

D. How can you change the initial information?

E. How would the solution probably look?

F. HINTS

1) look for patterns

2) simplify the problem

3) examine your assumptions

4) solve for the general or special case

5) work backwards from an assumed solution

6) draw a diagram, make a graph, build a chart

7) translate information into an equation

III. Work Out Plan

A. Which strategies are most likely to work?

B. Are you doing what you had planned?

C. Hints

1) carry through your plan

2) be aware of alternative strategies

IV. Examine Solution

A. Does your solution fit all original criteria?

B. Does your solution resemble your original prediction?

C. Hints

1) check reasonableness of your answer

2) check accuracy of your answer (math units or word choice)

3) remember problem solving strategies you used

V. Got It!...or Go Back

A. Did you reach your goal or solve your problem?

1) If yes, task complete.

2) If no, retrace steps to see if you

a) correctly understood the problem

b) chose an appropriate strategy

c) accurately carried through the plan

d) carefully examined your results

B. Hints

1) check original wording of the problem

2) check initial conditions and intended outcomes

3) explain to yourself the steps you used

4) work through your thinking processes one more time

There are various approaches to solving most problems. Steps two and three of the model described here involve the selection and application of a strategy or strategies for solving a problem; they are key pieces of the puzzle.

Pretend that you are trying to determine the number of handshakes a group of sixteen people must make so that every person shakes everyone else's hand once. One strategy is to experiment with sixteen real people acting out the problem and counting the handshakes.

Another strategy is to examine the problem using a small scale model (reduce the number of people shaking hands), keep track of data on a table (organized listing) and look for patterns that appear (pattern recognition). Using this approach we begin with two people shaking hands, then three, then four, and so on. The data can be collected in a table that keeps track of people and handshakes:

Data on the Number of Handshakes

Number of people	1	2	3	4	5	...	16
Number of handshakes	0	1	3	6	10	...	?

Some students may continue the table for 6, 7, 8...16 people. Others may be able to work with the pattern in the second row, noticing an increase of one between the first two terms, an increase of two between the next two terms, and so on, until the general pattern of $n-(n-1)/2$ is recognized. Students with a more advanced math background may recognize this as the method of finite differences.

Another method of solving this problem is logical deduction. Since every person will shake hands with every other person, there will be 16 times 15 handshakes; but since A shaking B is the same as B shaking A, there will be one-half as many handshakes needed, resulting in (16) (15) / 2. So, 120 handshakes are needed.

This problem was solved using a variety of strategies, none of which is any more important or valuable than another. What is important, though, is that students work through the problem using a specific process.

A problem solving tool with high potential

There is a growing collection of computer software which purports to train

students in the development of thinking skills. Many of these packages operate within a rather broad framework of objectives; some are designed to train students in the discrete operations such as recall, extrapolation, and synthesis of information, while others are intended to teach more all-encompassing processes such as critical thinking or problem solving.

There is a diversity in the design and intent of microcomputer software used to teach these skills. This parallels the problem educators have deciding which thinking skills should be taught and what the components should be. Teachers must also decide how to (or even whether to) integrate thinking skills within content areas across grade levels, and how to measure student competence in using these skills.

MECC Courseware: Problem Solving Strategies

Problem Solving Strategies is a courseware package produced by the Minnesota Educational Computing Consortium. Designed for teaching problem solving techniques to middle school and junior high school students, the product consists of one diskette for the Apple // microcomputer and a seventy-five page support manual containing background information on the content, instructions for classroom use, reproducible student handouts to accompany each program, and ideas for extending the strategies taught.

The package introduces students to three problem solving strategies: trial and error (guess and check), exhaustive listing, and simplifying the problem. Student handouts assist in the use of three problem solving tools: drawing a diagram, making a chart to collect data, and finding a pattern.

There are four separate programs on the diskette. Two programs (Diagonals, Squares) introduce and provide practice on applying strategies to solve puzzle problems.

Another is a game (Thinking With Ink) in which students compete in painting a pattern of rectangles at the lowest possible dollar cost. The fourth program is a game (Pooling Around) that simulates the action of a pool ball bouncing on various sized tables and gives students practice in collecting data, discovering patterns, and predicting outcomes.

All of the problem situations on the diskette are "puzzle" problems rather than realistic problems you might encounter in everyday life. These were chosen so that all students would possess about the same amount of information on the problem. Answers to these puzzles do not have any inherent value; it is the process of solving the problems that is important.

Background material in the manual emphasizes that other strategies are possible, that some strategies are more appropriate for a given problem than others, that strategies often overlap, and that the process can be improved using a systematical approach.

Followup information encourages students to share and discuss strategies they have used, to apply these strategies to real-life problems, and to understand that differences in individual thinking styles affect the choice of problem solving strategies.

The following pages illustrate the flow of one program to be demonstrated during the presentation.

mecc problem solving strategies: diagonals

PROGRAM PREVIEW

In this program students explore three problem-solving strategies applied to one puzzle problem: the total number of diagonals in a dodecagon. Only one problem situation is used to illustrate all three strategies, so that students can concentrate on the strategies rather than the peculiarities of several problem situations.

The program is made up of four sections (Figure 1) which students proceed through sequentially. If students do not complete the program in one session, they may stop their work and return, in the next class sessions, to the place where they left off. This can be done by answering "yes" to the question "Have you used this program before?" Then selecting from the menu shown in Figure 1.

Students are led through an exploration of the problem (Figure 2) to encourage them to fully understand the problem before trying to solve it. Both the concepts "dodecagon" and "diagonal" are investigated in this section.

Students who claim to understand these concepts must show that they do understand by answering a question on the concept. If they answer incorrectly, they will proceed through the tutorial on the concept.

Students who demonstrate their understanding of these concepts are branched to the next section, bypassing the tutorials on exploring the problem.

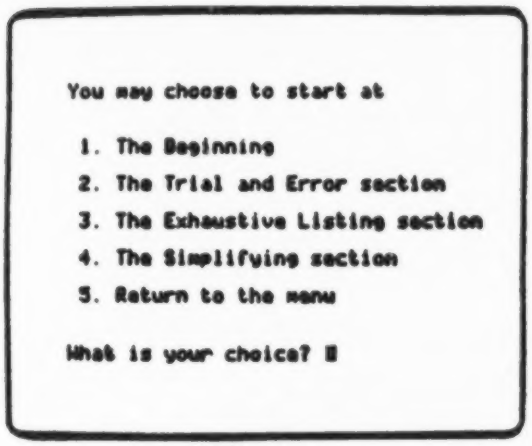
You may choose to start at
1. The Beginning
2. The Trial and Error section
3. The Exhaustive Listing section
4. The Simplifying section
5. Return to the menu
What is your choice?

Figure 1

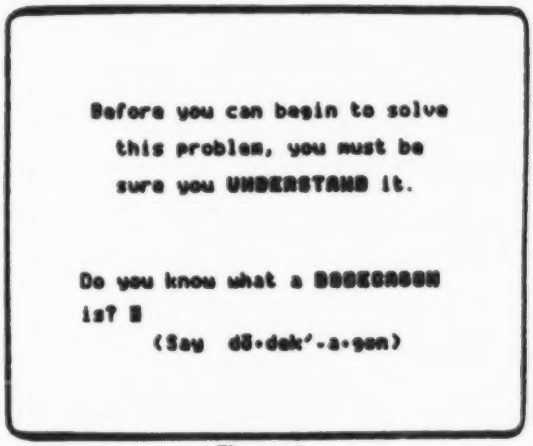
Before you can begin to solve
this problem, you must be
sure you UNDERSTAND it.
Do you know what a DODECAGON
is?
(Say dō·dek'-a·gon)

Figure 2

PROGRAM PREVIEW (continued)

The three strategies are listed (Figure 3). Through Trial and Error the students then proceed, receiving feedback as to whether their guesses are too high or too low (Figure 4).

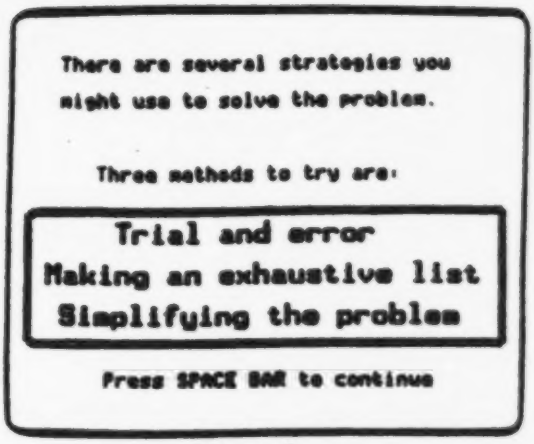
There are several strategies you
might use to solve the problem.
Three methods to try are:
Trial and error
Making an exhaustive list
Simplifying the problem
Press SPACE BAR to continue

Figure 3

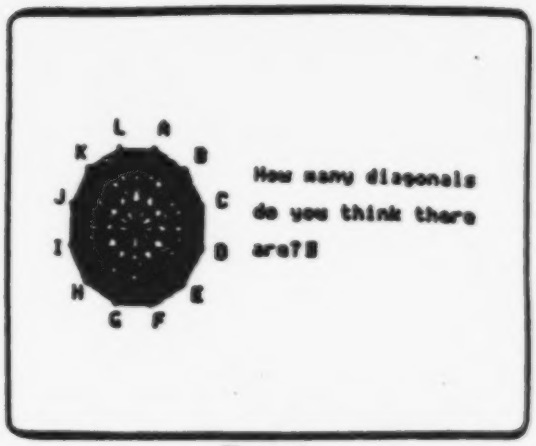

Figure 4

After students guess correctly or choose to stop guessing, they are given information on the advantages and disadvantages of the trial and error method (Figure 5).

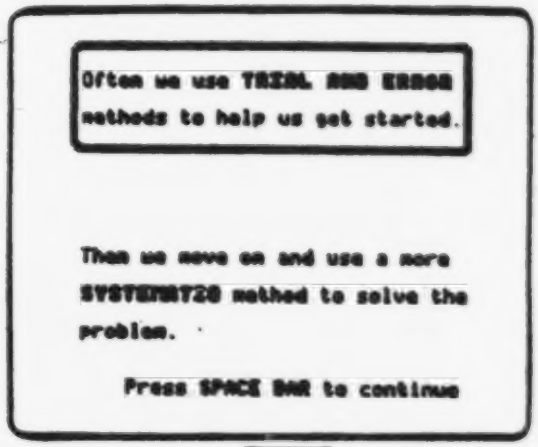
Often we use TRIAL AND ERROR
methods to help us get started.
Then we move on and use a more
SYSTEMATIC method to solve the
problem.
Press SPACE BAR to continue

Figure 5

PROGRAM PREVIEW (continued)

The next strategy, the exhaustive listing method, is described on the next screen (Figure 6). Students count diagonals with the help of the computer, which checks for duplication and reports whether any were missed (Figure 7). Students can exit this section of the program by answering "no" when asked if they want to fill in the missing diagonals. They then receive information on when to use exhaustive listing.

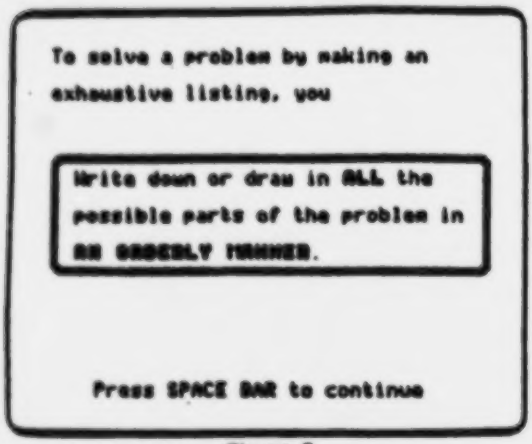
To solve a problem by making an exhaustive listing, you
Write down or draw in ALL the possible parts of the problem in AN ORDERLY MANNER.
Press SPACE BAR to continue

Figure 6

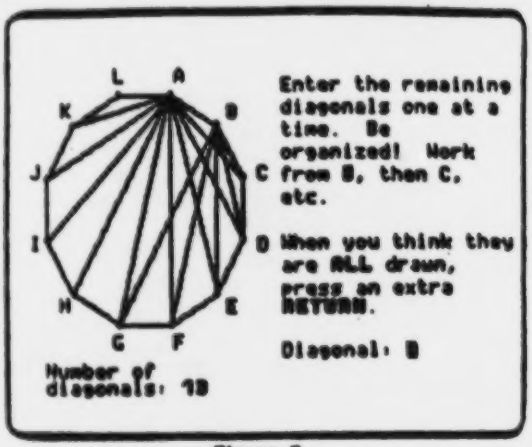

Figure 7

The final section presents the strategy of simplification (Figure 8). In the "Simplifying the Problem" section students examine simpler cases beginnning with a triangle, then a quadrilateral, etc. (Figure 9).

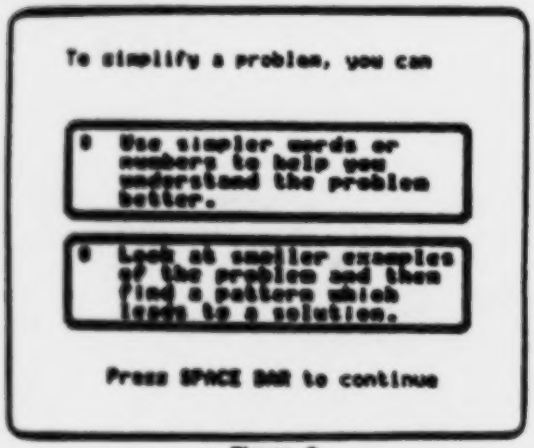
To simplify a problem, you can
1 Use simpler words or numbers to help you understand the problem better.
2 Look at smaller examples of the problem and then find a pattern which leads to a solution.
Press SPACE BAR to continue

Figure 8

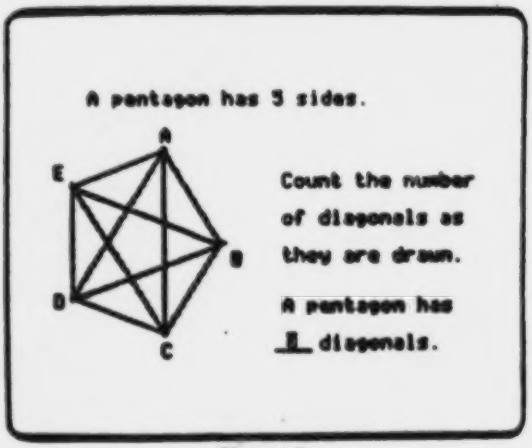

Figure 9

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PROGRAM PREVIEW (continued)

The data is collected in a chart, and students are led to finding a pattern in the data (Figure 10 and 11).

If we find a PATTERN, then
we can predict the number of
diagonals for figures like a
dodecagon without having to draw
and count all the diagonals.
Press SPACE BAR to continue

Figure 10

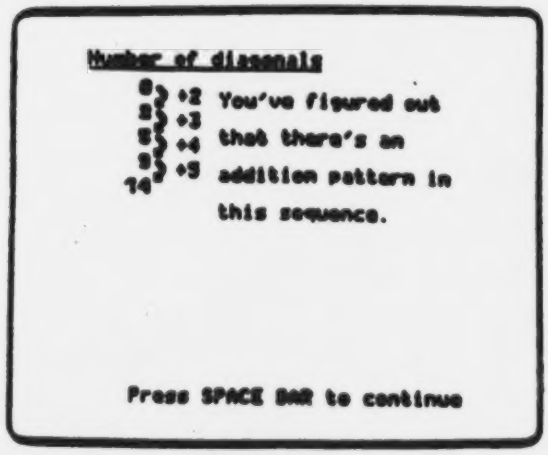


Figure 11

Finally students apply the patterns they found to other figures (Figure 12).

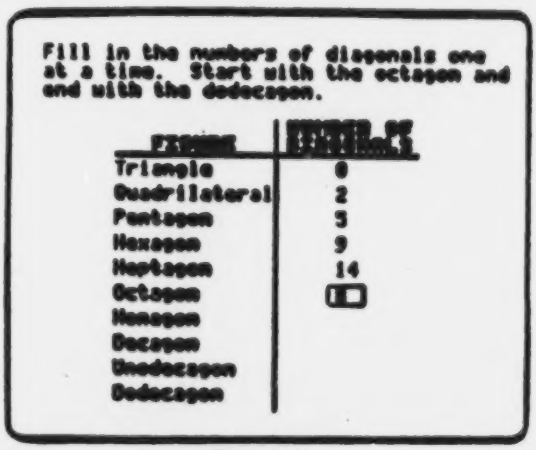


Figure 12

PROBLEM SOLVING STRATEGIES

DIAGONALS EXHAUSTIVE LISTING WORKSHEET

1

Name _____

Use this worksheet to record the diagonals as you count them in the Exhaustive Listing section of DIAGONALS.

A diagonals	B diagonals	C diagonals	D diagonals	E diagonals	F diagonals
AC AD					
Total___	Total ___	Total ___	Total ___	Total ___	Total ___

G diagonals	H diagonals	I diagonals	J diagonals	K diagonals	L diagonals
Total ___	Total ___	Total ___	Total ___	Total ___	Total ___

GRAND TOTAL OF DIAGONALS _____

PROBLEM SOLVING STRATEGIES

DIAGONALS SIMPLIFYING CHART

2

Name _____

Fill in the number of diagonals for each figure as you work through the simplifying section of DIAGONALS. Fill in the missing names.

Figure	Figure name	Number of diagonals
	triangle	_____
	quadrilateral	_____
	pentagon	_____
	hexagon	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____

PROBLEM SOLVING STRATEGIES

DIAGONALS
OTHER WAYS TO SOLVE THIS PROBLEM

3

Name _____

There usually are many ways to solve a problem. Here are two that are <u>not</u> shown in the program DIAGONALS. Study these strategies, then apply them to another problem by filling the blanks.

DEDUCTIVE REASONING

There are 12 vertices
Each vertex is the end point of 9 diagonals
Each diagonal has exactly 2 end points, that is, it connects 2 vertices
So multiply 9 times 12 then divide by 2

$\frac{9 \times 12}{2} = \frac{108}{2} = 54$ diagonals

Apply this strategy to the problem of the number of diagonals in a 13-sided polygon.

_____x_____ = ___ diagonals

FIND A PATTERN IN EXHAUSTIVE LISTING

List the number of diagonals from each vertex counting each diagonal only once; then find a pattern in these numbers.

Vertex	A	B	C	D	E	F	G	H	I	J	K	L
no. of diagonals	9	9	8	7	6	5	_	_	_	_	_	_

9 + 9 + 8 + 7 + 6 + 5 + 4 + 3 + 2 + 1 + 0 + 0 = 54 Total

Apply this strategy to the case of a 13-sided figure.

Vertex	A	B	C	D	E	F	G	H	I	J	K	L	M
no. of diagonals	10	_	_	_	_	_	_	_	_	_	_	_	_

10 + _ + _ + _ + _ + _ + _ + _ + _ + _ + _ + _ + _ + = _

DIAGONALS PROBLEM SOLVING STRATEGIES

4

DEFINITIONS

Here are definitions for three problem-solving strategies.

TRIAL AND ERROR — (GUESS AND CHECK)

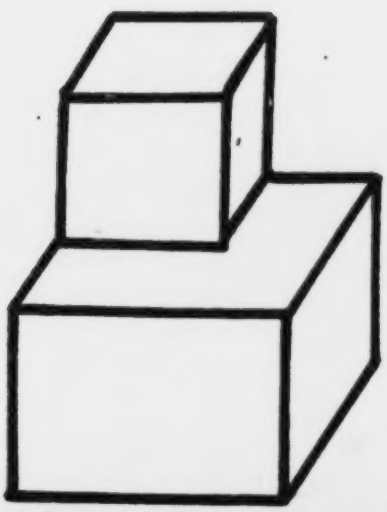
a strategy in which you make a guess (or trial) based on what you know about the problem. Then you find out how close your guess was (the amount of "error"). This new information helps you make another, better guess. It may also help you plan a new strategy.

EXHAUSTIVE LISTING —

a strategy in which you list or draw all the possibilities of the problem situation. You may then count up all the possibilities, choose a solution from the list, or find a pattern that can be generalized.

SIMPLIFYING THE PROBLEM —

a strategy in which you explore a simpler case of the problem. You solve this simpler problem. You can then generalize from the solution of the simpler case to solve the original problem.



DIAGONALS PROBLEM SOLVING STRATEGIES

5

EXAMPLES

Here are examples of three problem-solving strategies.

TRIAL AND ERROR EXAMPLE

Problem: You want to guess a friend's secret number between 1 and 100.

Solution: Guess a number. Your friend tells you if the guess is correct, too high, or too low. If you're correct, you stop of course. Otherwise you guess again, and your next guess depends on whether your earlier guess was too high or too low.

EXHAUSTIVE LISTING EXAMPLE

Problem: How many different double dip ice cream cones can you make if you have 4 different flavors of ice cream? (assume you don't care which flavor is on top!)

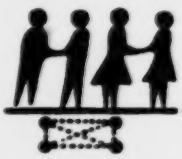
Solution:

The answer is 10.

SIMPLIFYING THE PROBLEM EXAMPLE

Problem: Ten people at a party all shook hands once with each of the others. How many handshakes took place?

Solution:



if 2 people, 1 handshake
if 3 people, 3 handshakes
if 4 people, 6 handshakes
if 5 people, 10 handshakes
. .
. .
. .

The pattern is 1, 3, 6, 10, . . .

so the next numbers would be

1, 3, 6, 10, 15, 21, 28, 36, 45.

The answer is 45.

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